What is claimed is:

1. A method of shifting a bandgap energy of a semiconductor quantum well layer, comprising the steps of:

introducing ions into a quantum well structure at a first elevated temperature, wherein the quantum well structure comprises a plurality of material layers formed on a semiconductor substrate including a quantum well layer disposed between an upper barrier layer and a lower barrier layer;

thermally pre-annealing the quantum well structure at a second elevated temperature and for a pre-anneal time period that do not induce quantum well intermixing in the quantum well structure; and

thermally annealing the quantum well structure at a third elevated temperature and for an anneal time period sufficient to induce quantum well intermixing in, and a shifting of a bandgap energy of, the quantum well layer.

2. The method of claim 1, wherein the quantum well structure further includes an upper cladding layer disposed over the upper barrier layer, and wherein the introduction of ions into the quantum well structure includes introducing the ions into the cladding layer.

3. The method of claim 2, wherein the quantum well structure further includes a plurality of quantum well layers separated by a plurality of barrier layers.

4. The method of claim 1, wherein the introduction of the ions creates point defects in the quantum well structure, and wherein the thermal pre-annealing moves the point defects closer to the quantum well layer without inducing quantum well intermixing in the quantum well layer.

5. The method of claim 1, wherein the first elevated temperature is at least approximately 200 °C, but does not exceed a temperature that causes thermal decomposition of the quantum well structure.

6. The method of claim 1, wherein the second elevated temperature is between approximately 300 °C and 650 °C.

7. The method of claim 1, wherein the third elevated temperature is greater than the second elevated temperature.

8. The method of claim 7, wherein the third elevated temperature is between approximately 675 °C and 750 °C.

9. The method of claim 1, wherein the ions introduced into the quantum well structure are at least one of arsenic ions, phosphorous ions, argon ions, xenon ions, oxygen ions and gallium ions.

10. The method of claim 9, wherein the introduction of ions is performed with an implant energy no greater than approximately 360 keV and a dosage no greater than approximately 10^{14} cm^{-2}.

11. The method of claim 1, further comprising the step of forming a capping layer of material over the quantum well structure after the introduction of the ions.

12. The method of claim 1, wherein the introduction of the ions is performed only on one or more selected portions of the quantum well structure.

13. The method of claim 12, further comprising the step of forming a patterned mask layer over the quantum well structure for selectively blocking at least some of the ions from being introduced into portions of the quantum well structure.

14. The method of claim 13, wherein the patterned mask layer is formed of a material having a thermal coefficient of expansion that is significantly greater than that of the quantum well structure.

15. The method of claim 13, wherein the formation of the patterned mask layer includes the steps of forming a masking material over the quantum well structure having a thickness sufficient to block the ions from being introduced into the quantum well structure, and selectively removing portions of the masking material to form window regions in the mask layer through which at least some of the ions can pass and be introduced into the quantum well structure.

16. The method of claim 15, wherein thicknesses of the masking material in the window regions vary to allow varying amounts of the ions to pass therethrough and be introduced into the quantum well structure.

17. The method of claim 16, wherein for at least one of the window regions, all the masking material is removed so that the one window region does not block ion incident thereon.

18. The method of Claim 1, wherein the annealing step is carried out with an overpressure of a Group V material.

19. The method of Claim 1, wherein the annealing step is carried out with an overpressure of arsenic.

20. A method of making a multiple bandgap semiconductor device, comprising the steps of:

forming a quantum well structure, wherein the quantum well structure comprises a plurality of epitaxial layers disposed over a substrate including a quantum well layer disposed between upper and lower barrier layers;

forming a patterned mask over the quantum well structure with sufficient thickness to block ions incident thereon, wherein the patterned mask includes a plurality window portions of reduced thickness for passing therethrough at least some ions incident thereon;

heating the quantum well structure to a first elevated temperature;

bombarding the patterned mask with ions, wherein at least some of the ions incident on the window portions pass therethrough and are introduced into the heated quantum well structure;

thermally pre-annealing the quantum well structure at a second elevated temperature and for a pre-annealing time period that do not induce quantum well intermixing in the quantum well structure; and

thermally annealing the quantum well structure at a third elevated temperature greater than the second elevated temperature, and for an anneal time period, sufficient to induce quantum well intermixing in, and a shifting of a bandgap energy of, the quantum well layer.

21. The method of claim 20, wherein the formation of the quantum well structure further comprises the step of forming an upper cladding layer over the upper barrier layer, wherein the ions are introduced into the cladding layer.

22. The method of claim 21, wherein the formation of the quantum well structure further comprises the step of forming a plurality of quantum well layers separated by a plurality of barrier layers.

23. The method of claim 20, wherein the introduction of the ions creates point defects in the quantum well structure, and wherein the thermal pre-annealing moves the point defects closer to the quantum well layer without inducing quantum well intermixing in the quantum well layer.

24. The method of claim 20, wherein the first elevated temperature is at least 200 °C, but does not exceed a temperature that causes thermal decomposition of the quantum well structure.

25. The method of claim 20, wherein the second elevated temperature is between 300 °C and 650 °C.

26. The method of claim 20, wherein the third elevated temperature is between 675 °C and 750 °C.

27. The method of claim 20, wherein the ions introduced into the quantum well structure are at least one of arsenic ions, phosphorous ions, argon ions, xenon ions, oxygen ions and gallium ions.

28. The method of claim 27, wherein the bombardment of ions is performed with an implant energy no greater than 360 keV and a dosage no greater than 10^{14} cm^{-2}.

29. The method of claim 18, further comprising the step of forming a capping layer of material over the quantum well structure after the introduction of the ions, wherein the capping layer reduces outdiffusion of elements of the quantum well structure.

30. The method of claim 20, wherein the patterned mask is formed of a material having a thermal coefficient of expansion that is significantly greater than that of the quantum well structure.

31. The method of claim 20, wherein the formation of the patterned mask includes the steps of:

forming a masking material over the quantum well structure having a thickness sufficient to block the ions from being introduced into the quantum well structure; and

selectively removing portions of the masking material to form the window regions in the mask.

32. The method of claim 31, wherein the thicknesses of the masking material in the window regions vary to allow varying amounts of the ions to pass therethrough and be introduced into the quantum well structure.

33. The method of claim 32, wherein for at least one of the window regions, all the masking material is removed so that the one window region does not block ions incident thereon.

34. The method of Claim 18, wherein the annealing step is carried out with an overpressure of a Group V material.

35. The method of Claim 18, wherein the annealing step is carried out with an overpressure of arsenic.